Mapping Evapotranspiration in Idaho with Landsat

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Stanford Water in the West Uncommon Dialogue on Groundwater Technology, April 20, 2012
Why is measuring Evapotranspiration (ET) important

- ET is the water consumed by irrigated agriculture
- Important for administration, management, and planning of water resources
- Irrigated agriculture in Idaho
  - 3.4 million acres
  - Accounts for over 90% of the water consumed
- Irrigation in the US
  - 50 million acres agriculture, 32 million acres recreational
  - Accounts for over 80% of the water consumed
Ground-based ET

- **Potential ET** using crop coefficients
  - Needs crop type acres and stage of growth
  - Produces one ET value per county

Satellite-based ET

- **Actual ET** from Landsat using METRIC
  - No crop information required
  - ET per pixel can be summed by field
Landsat

- USGS/NASA mission
- L5 launched 1984 (halted November 2011)
- L7 launched 1999 (anomaly May 2003)
- 30 meter pixels
- 16 day cycle
- 100 by 100 miles
- Free

Landsat 8 will launch in January 2013
Landsat 9?
Why not use other satellites

- MODIS: 500 meter pixels
- AVHRR: 1000 meter pixels
- SPOT: no thermal band
- IRS AWiFS: no thermal band
- Aster: for research
Landsat Thermal Band

- Required for surface temperature
- Landsat is the only operational satellite with a “thermal band” and a pixel size small enough to map ET for individual fields!
METRIC

Mapping EvapoTranspiration at high Resolution with Internalized Calibration

- Satellite-based energy balance model that computes and maps actual ET
- Internalized Calibration ties down ET to weather data
- Over 90% accuracy compared to precision weighing lysimeter
Energy Balance for ET

ET is calculated as a “residual” of the energy balance

$$ET = R_n - G - H$$

The energy balance includes all major sources ($R_n$) and consumers (ET, G, H) of energy.
Energy balance computes “actual” ET

Can ‘see’ impacts on ET caused by:

- water shortage
- disease
- crop variety
- planting density
- cropping dates
- salinity
- management
- wet soil
Weather Data

In METRIC, Weather Data are used for:

*Wind speed* for sensible heat flux calculation

*Reference ET* for calibrating the Energy Balance

*Reference ET* to extrapolate ET
  - 24-hour period
  - Days between images
Landsat, south-central Idaho (8/14/2000)

- Thousand Springs
- Twin Falls
- Burley
- Wood River Valley
- Craters of the Moon
- Lake Walcott

- Dairy area (corn, alfalfa)
- recent burn
- basalt
Net Radiation (8/14/2000)

- Thousand Springs
- Twin Falls
- Burley
- Wood River Valley
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**Legend:**
- $R_n$: Net Radiation (W/m$^2$)
- $H$: Soil Heat flux
- $ET$: Evapotranspiration
- $G$: Ground Heat flux

Net Radiation (W/m$^2$)
- 0
- 200
- 400
- 600
- 800+

**Recent Burn Area:**
- Wood River Valley
- Thousand Springs
- Twin Falls
- Burley
- Lake Walcott

**Dairy Area:**
- Wood River Valley
- Thousand Springs
- Twin Falls
- Burley
- Lake Walcott

**Basalt Area:**
- Wood River Valley
- Thousand Springs
- Twin Falls
- Burley
- Lake Walcott

**Craters of the Moon:**
- Thousand Springs
- Twin Falls
- Burley
- Lake Walcott

**Lake Walcott:**
- Thousand Springs
- Twin Falls
- Burley

**Dairy Area (corn, alfalfa):**
- Thousand Springs
- Twin Falls
- Burley
- Lake Walcott
Ground Heat Flux (8/14/2000)

Soil Heat Flux (W/m\(^2\))

Rn, H, ET

Thousand Springs
Twin Falls
Burley
Craters of the Moon
Wood River Valley
Dairy area (corn, alfalfa)
recent burn
basalt
Lake Walcott

Soil Heat Flux (W/m\(^2\))

0
50
100
150
200+
Heat Flux to Air (8/14/2000)

Sensible Heat \( (W/m^2) \)

Recent burn
Dairy area (corn, alfalfa)
Basalt
Craters of the Moon
Wood River Valley
Thousand Springs
Lake Walcott
Burley
Dairy area
Twin Falls

0
100
200
300
400+

\( R_n \)
\( H \)
\( ET \)
\( G \)
Instantaneous ET (8/14/2000)

Thousand Springs
Twin Falls
Burley

Wood River Valley
Craters of the Moon
Lake Walcott

Dairy area (corn, alfalfa)
recent burn
basalt

Latent Heat (W/m²)

0
100
200
300
400+

N
24-hour ET (8/14/2000)

- Thousand Springs
- Twin Falls
- Burley
- Wood River Valley
- Craters of the Moon
- Dairy area (corn, alfalfa)
- recent burn
- basalt
- Lake Walcott

Evapotranspiration (mm/day)
- 0.0
- 1.5
- 3.0
- 4.5
- 6.0
- 7.5
- 8.2

100 miles
Comparison with Lysimeter Measurements

Lysimeter at Kimberly (Wright) 1968-1991
Seasonal ET for sugar beets at the Kimberly Research Station, April to September, 1989.
Applications in Idaho

- Hydrologic modeling
- Water planning
- Water administration
Hydrologic Modeling

Eastern Snake Plain Aquifer Model
Developing METRIC ET data from 1986 to present
Eastern Snake Plain Aquifer Model

METRIC ET data

- More accurately calibrate the groundwater model
- Improve accuracy of depletions and recharge estimates
- Shows long term trends in ET
## METRIC ET for Irrigated Land by Irrigation Entity

<table>
<thead>
<tr>
<th>Irrigation Entity</th>
<th>Mean ET mm</th>
<th>Acres</th>
<th>ET Volume ac-ft</th>
<th>ET ac-ft/acre</th>
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</thead>
<tbody>
<tr>
<td><strong>2000</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>American Falls Reservoir Dist #2</td>
<td>815</td>
<td>86,932</td>
<td>232,592</td>
<td>2.68</td>
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<tr>
<td>North Side Canal Co LTD</td>
<td>859</td>
<td>204,558</td>
<td>576,611</td>
<td>2.82</td>
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<tr>
<td>Irrigation Entities Overlap Area</td>
<td>828</td>
<td>5,146</td>
<td>13,971</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td>296,636</td>
<td>823,175</td>
<td>2.78</td>
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<td><strong>2002</strong></td>
<td></td>
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<tr>
<td>American Falls Reservoir Dist #2</td>
<td>657</td>
<td>97,590</td>
<td>210,332</td>
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<tr>
<td>North Side Canal Co LTD</td>
<td>768</td>
<td>210,827</td>
<td>530,939</td>
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<tr>
<td>Irrigation Entities Overlap Area</td>
<td>779</td>
<td>5,389</td>
<td>13,775</td>
<td>2.56</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td>313,805</td>
<td>755,046</td>
<td>2.41</td>
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<td><strong>2006</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>American Falls Reservoir Dist #2</td>
<td>796</td>
<td>100,004</td>
<td>261,306</td>
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<td>North Side Canal Co LTD</td>
<td>831</td>
<td>215,011</td>
<td>586,337</td>
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<td>Irrigation Entities Overlap Area</td>
<td>837</td>
<td>5,385</td>
<td>14,795</td>
<td>2.75</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td>320,399</td>
<td>862,438</td>
<td>2.69</td>
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<td><strong>2008</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>American Falls Reservoir Dist #2</td>
<td>843</td>
<td>91,441</td>
<td>252,816</td>
<td>2.76</td>
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<tr>
<td>North Side Canal Co LTD</td>
<td>915</td>
<td>206,796</td>
<td>620,615</td>
<td>3.00</td>
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<tr>
<td>Irrigation Entities Overlap Area</td>
<td>927</td>
<td>5,109</td>
<td>15,545</td>
<td>3.04</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td>303,346</td>
<td>888,975</td>
<td>2.93</td>
</tr>
</tbody>
</table>

Potential METRIC Processing ESPA

1984 - too sparse
1985 - too sparse
1986 - yes (METRIC in Progress)
1987 - not as populated as 1986, but possible for METRIC
1988 - no April-May for METRIC on path 40
1989 - no Sept-Oct for METRIC on path 40, poor on path 39
1990 - possible METRIC on 40, not on 39
1991 - no
1992 - possible METRIC for 40 and 39
1993 - possible for METRIC, no April-May on 39
1994 - no May-June for METRIC path 40
1995 - no
1996 - yes (METRIC DONE)
1997 - yes, iffy METRIC for June-July on 39
1998 - no May for METRIC on 40 and 39
1999 - no for METRIC in spring
2000 - yes (METRIC DONE)
2001 - yes for METRIC on both paths
2002 - yes (METRIC DONE)
2003 - iffy for METRIC for both paths (path 40 DONE through August (no images after that))
2004 - yes for METRIC on both paths
2005 - iffy for METRIC
2006 - yes (METRIC DONE)
2007 - possible, but challenging for METRIC on path 40
2008 - yes (METRIC DONE)
2009 - yes (METRIC in Progress)
2010 - yes (METRIC in Progress)
2011 - yes for METRIC on both paths
Water Planning
ET by Land Use

- Used for estimates of future water demand
- Year 2000 land use data analyzed with year 2000 seasonal ET data
Water Administration
Litigation

- A&B Irrigation District water call
- Clear Springs Foods water call
Water Law Terms

- Water Right
  - Authorization to use water
  - Includes priority date and rate of flow/volume

- Call
  - When a senior water right holder experiences a water shortage they may place a call

- Curtailment Order
  - Defines how the state directs junior water right holders to stop diverting water in response to a call

- Mitigation Plan
  - Junior users response to a curtailment order
A&B Irrigation District Water Call

- A&B claimed that certain fields were short of water in 2006 due to diversions from junior ground water users

- METRIC ET showed that the fields had ET rates as high as surrounding fields that were not identified as water short
Year 2006: Mean Daily Evapotranspiration (ET)
Year 2006: Ratio of ETrF and NDVI (ET per amount of vegetation)
A&B Irrigation District Water Call

Summary

- Director issued order denying the call
- Hearing Officer agreed with the Director’s decision
- District Court affirmed the Director’s decision
- Idaho Supreme Court
  - Argued on February 28, 2012
  - Waiting for decision
Clear Springs Foods Water Call

Idaho Business News

Water curtailment ordered in Magic Valley

POSTED: 11:13 MDT Thursday, July 23, 2009
By IBR Staff

Idaho Department of Water Resources Interim Director Gary Spackman on July 22 issued a curtailment order to about 250 holders of 315 junior water rights in south central Idaho’s Magic Valley. The curtailment order is part of a continuing response to a water delivery call made in 2005 by senior water right holder Clear Springs Foods.

State goes ahead with first large-scale well closure of more than 300 water rights in M.V. 7/31/2009

Water districts have limited options, could file a stay
By Nate Poppino
Times-News writer

The Idaho Department of Water Resources will go forward this morning with a plan to shut off more than 300 water rights irrigating just less than 9,000 acres of Magic Valley farmland, the first wide-scale well curtailment to actually be carried out by the state.
Clear Springs Foods, Inc.
Annual Water Consumption = 4 million acre feet/year
(3 Trillion gallons; 5 Trillion liters)
Clear Springs Foods Water Call

Summary

- ESPA GW model used METRIC ET data
  - For model calibration
  - To select water rights to curtail

- No complaints from junior users about GW model or METRIC ET data
Aquifer Depletion
Aquifer Depletion

ESPA has ~ 4,000 monitored irrigation wells

What is the most efficient monitoring method?

**Present method:** power consumption coefficients

**Alternative method:** METRIC and Landsat

Compared 180 well-field combinations
Result

**PCC**
Cost: $119 per well

**METRIC**
Cost: $32 per field
Other states using METRIC

- Nevada
  - Water transfers to Reno and Las Vegas

- Nebraska
  - Over pumping of the Ogallala Aquifer

- Colorado
  - Kansas vs. Colorado over Arkansas River
  - Nebraska vs. Colorado over S. Platte River

- Wyoming
  - Nebraska vs. Wyoming over N. Platte River

- Oregon
  - Klamath Basin water shortages

- California
  - Imperial Irrigation District: water consumption by irrigation

- New Mexico
  - Middle Rio Grande: water consumption by agriculture and riparian systems

- Montana
  - Flathead Indian Reservation and ground water areas east of Helena: for improved irrigation water management and management of total depletion
Cost of METRIC

- About one year to develop monthly ET for 100,000 square kilometers (4 Landsat images)
- Cloudy areas require extra effort
- Other costs if you do it yourself
  - training
  - image processing and GIS software
  - disks for processing and storage
Concern about Landsat’s future

- Landsat 5 is 28 years old
  - Imaging halted November 2011 due to electronic component problem
- Landsat 7 is 13 years old
  - Scan line corrector failed March 2003
  - About 22% of each image is missing
  - Missing areas are filled in using ArcGIS tools
- Landsat 8 scheduled to launch January 2013
- Funding for Landsat 9 is uncertain
The Landsat Archive

- USGS EROS Data Center, Sioux Falls, SD
- ~ 3 million scenes
- July 1972 to present (thermal since 1984)
- Free
- http://earthexplorer.usgs.gov/
Summary

- METRIC computes “Actual ET”
  - Over 90% accurate
  - ET at the field level
  - ET by day, month, and year
  - ET from bare soil and vegetation
- Idaho and other states use METRIC operationally
- Landsat is the best satellite for mapping ET at the field level
More Information

www.idwr.idaho.gov/GeographicInfo/METRIC/et.htm
www.kimberly.uidaho.edu/water/metric
www.idwr.idaho.gov/geographicinfo/landsat/LandsatConcerns.htm
www.westernstatesetworkshop.com

Seasonal METRIC ET for 2000